NASA Exoplanet Update

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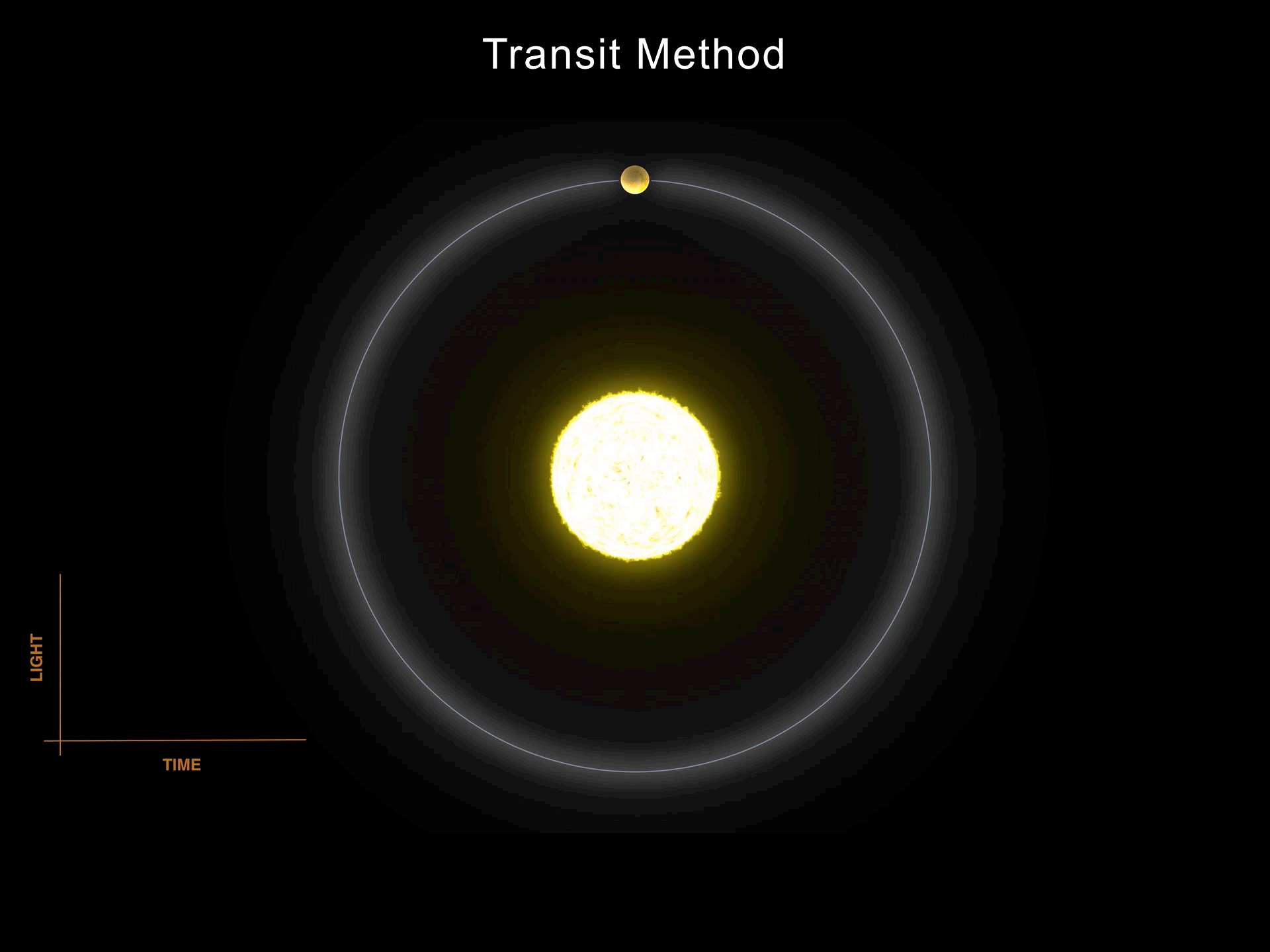
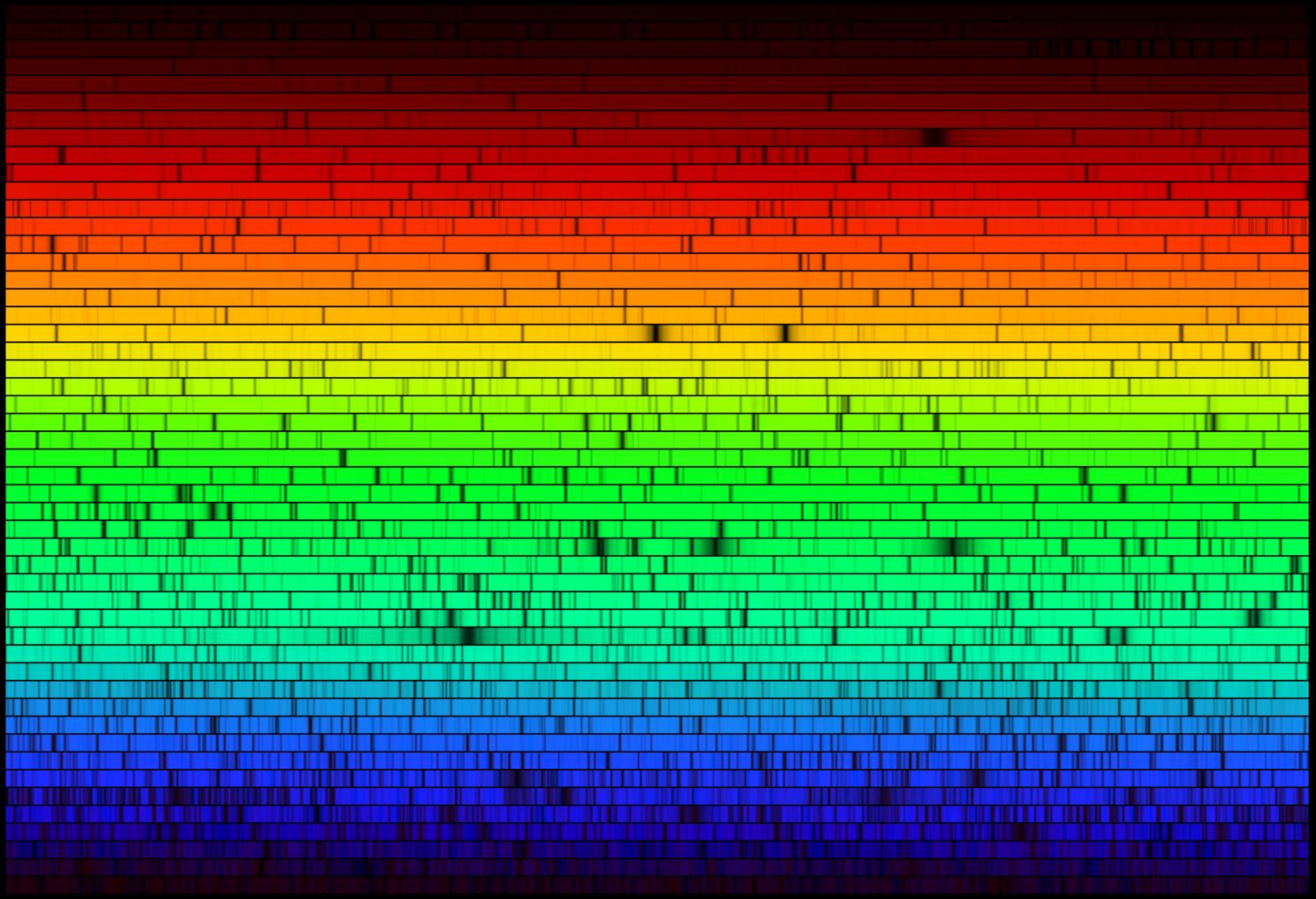
Jet Propulsion Laboratory
California Institute of Technology

Transit Method

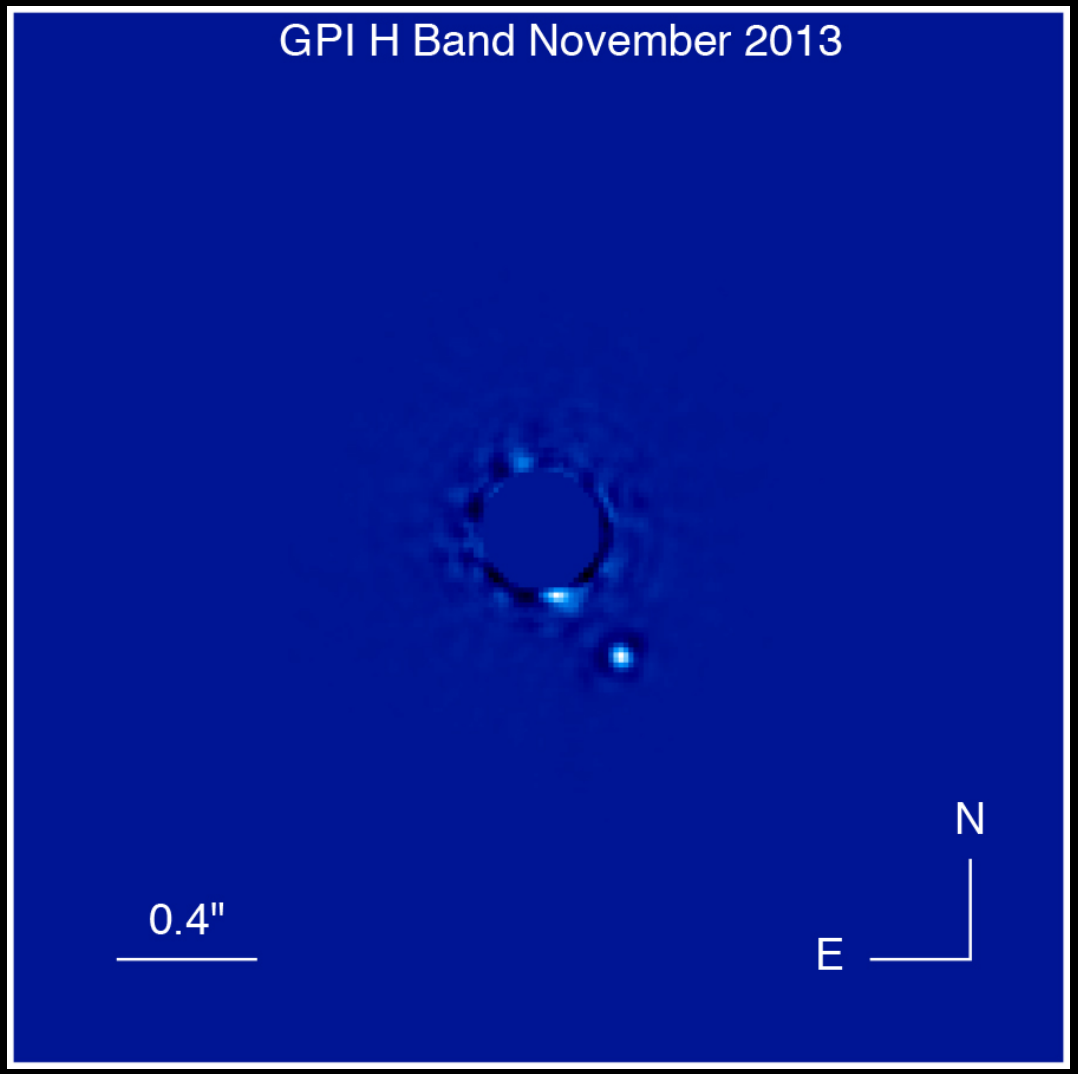


Radial Velocity Method

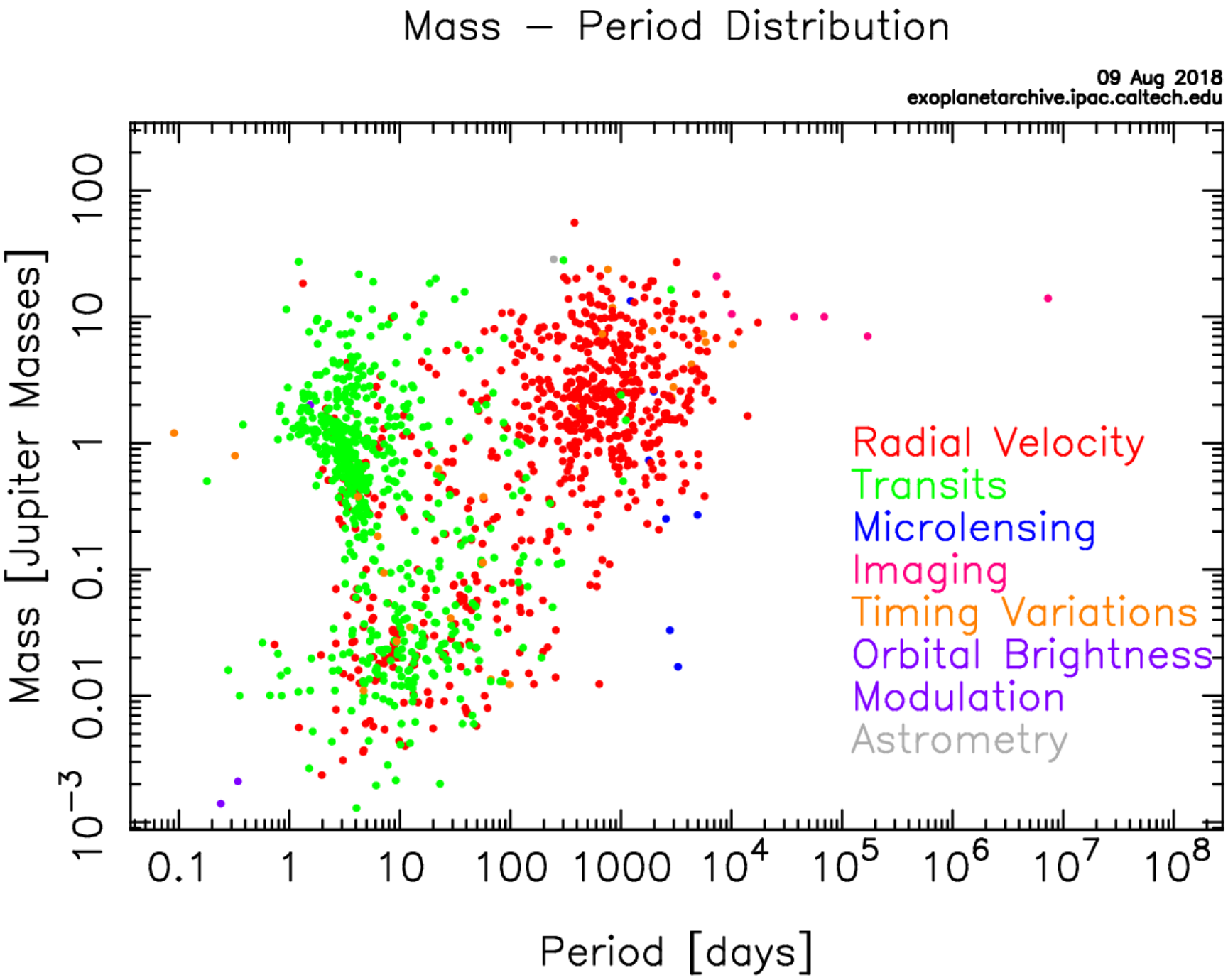


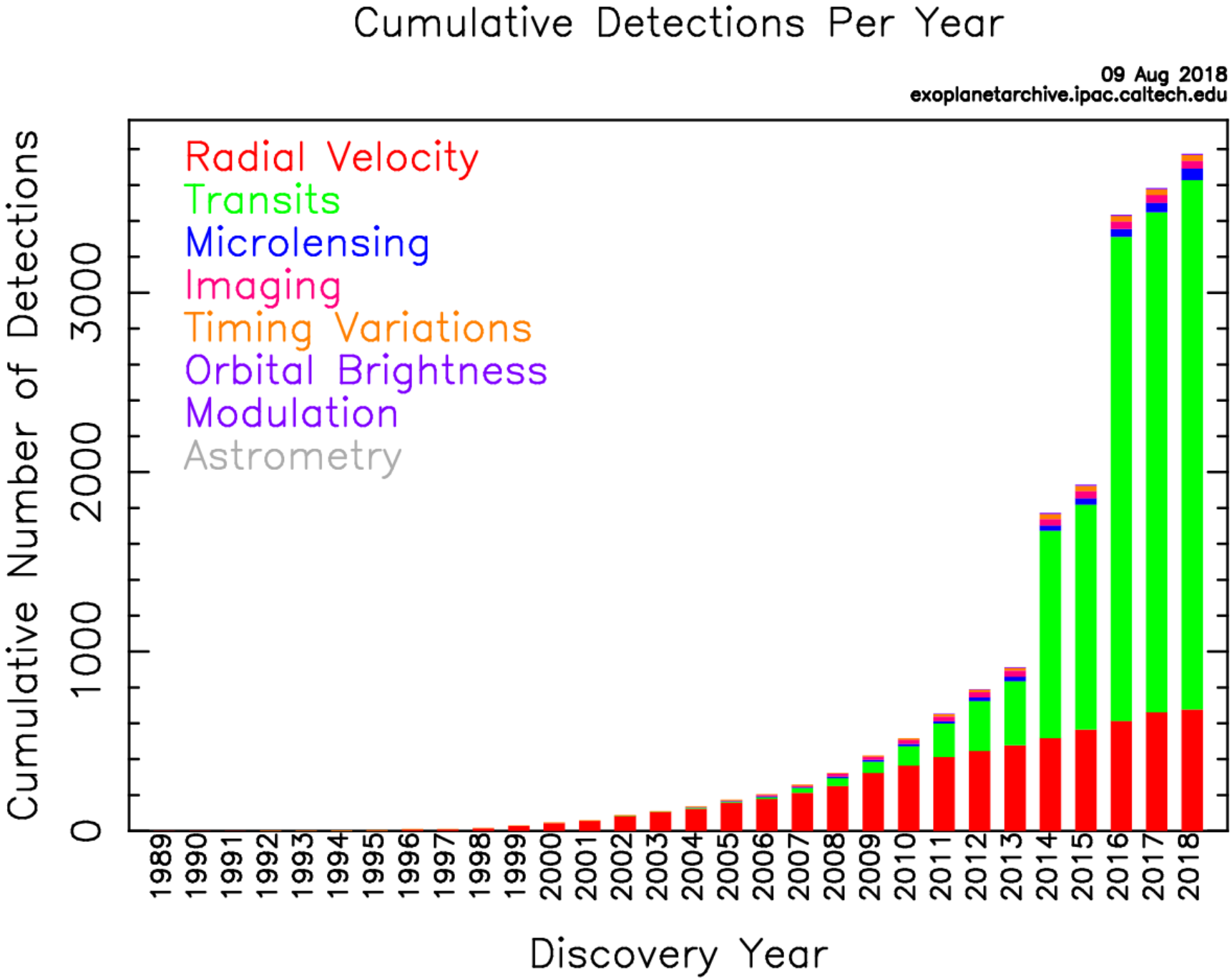
Credit: noao.gov

Direct Imaging

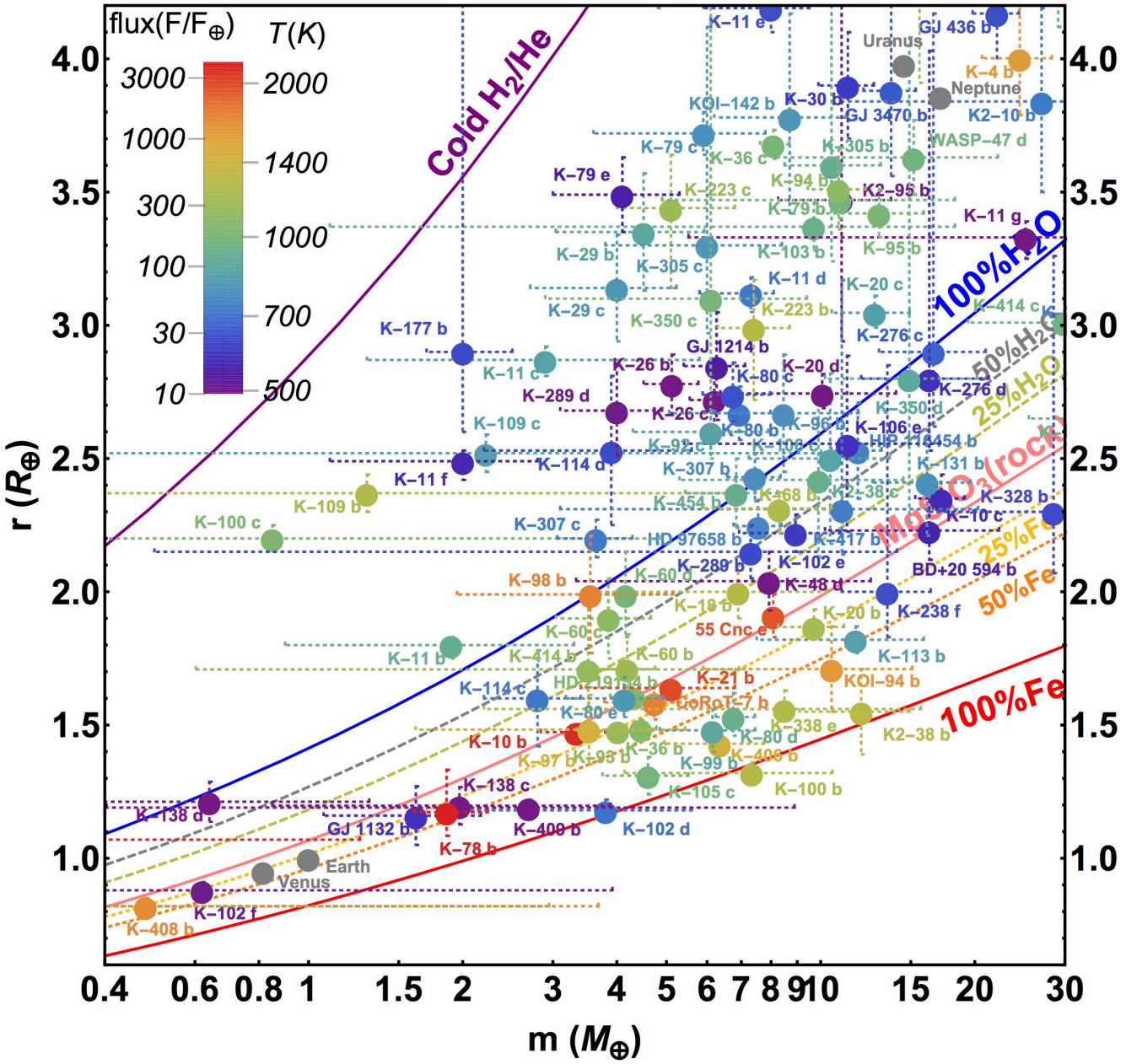


Credit: wfirst.gsfc.nasa.gov


Mass – Period Distribution
09 Aug 2018
exoplanetarchive.ipac.caltech.edu
Mass [Jupiter Masses]
10^{-3}
0.01
0.1
1
10
100
Period [days]
0.1
1
10
100
1000
10^4
10^5
10^6
10^7
10^8
Radial Velocity
Transits
Microlensing
Imaging
Timing Variations
Orbital Brightness Modulation
Astrometry


Cumulative Detections Per Year
09 Aug 2018
exoplanetarchive.ipac.caltech.edu
Radial Velocity
Transits
Microlensing
Imaging
Timing Variations
Orbital Brightness
Modulation
Astrometry
Cumulative Number of Detections
0
1000
2000
3000
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Discovery Year

Exoplanet Mass-Radius



Credit: www.cfa.harvard.edu

Exoplanet Missions

WFIRST

JWST[2]

PLATO

TESS

Kepler

CHEOPS[4]

LUVOIR[5]

Spitzer

Gaia

Hubble[1]

CoRoT[3]

Starshade Rendezvous[5]

HabEx[5]

OST[5]

NASA Missions

Non-NASA Missions

W. M. Keck Observatory

Large Binocular Telescope Interferometer

NN-EXPLORE

Ground Telescopes with NASA participation

[1] NASA/ESA Partnership
[2] NASA/ESA/CSA Partnership
[3] CNES/ESA
[4] ESA/Swiss Space Office

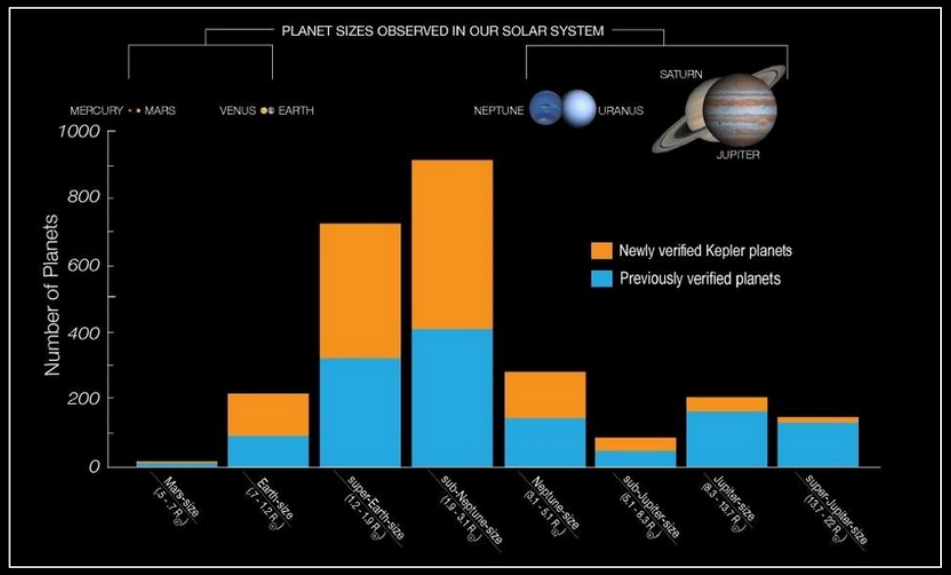
[5] 2020 Decadal Survey Studies

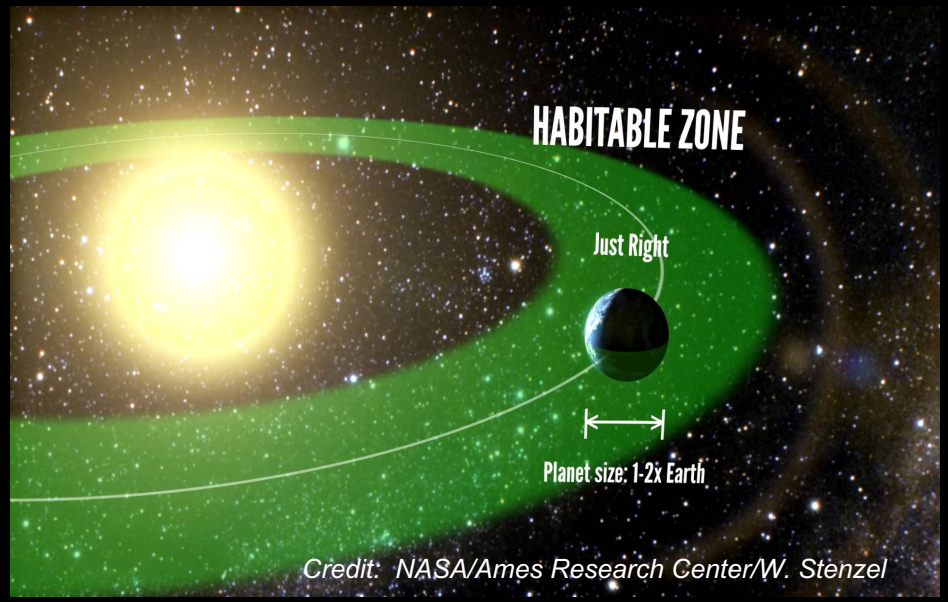
Key Kepler Results

1. On average there is at least one planet for each of the stars in the night sky

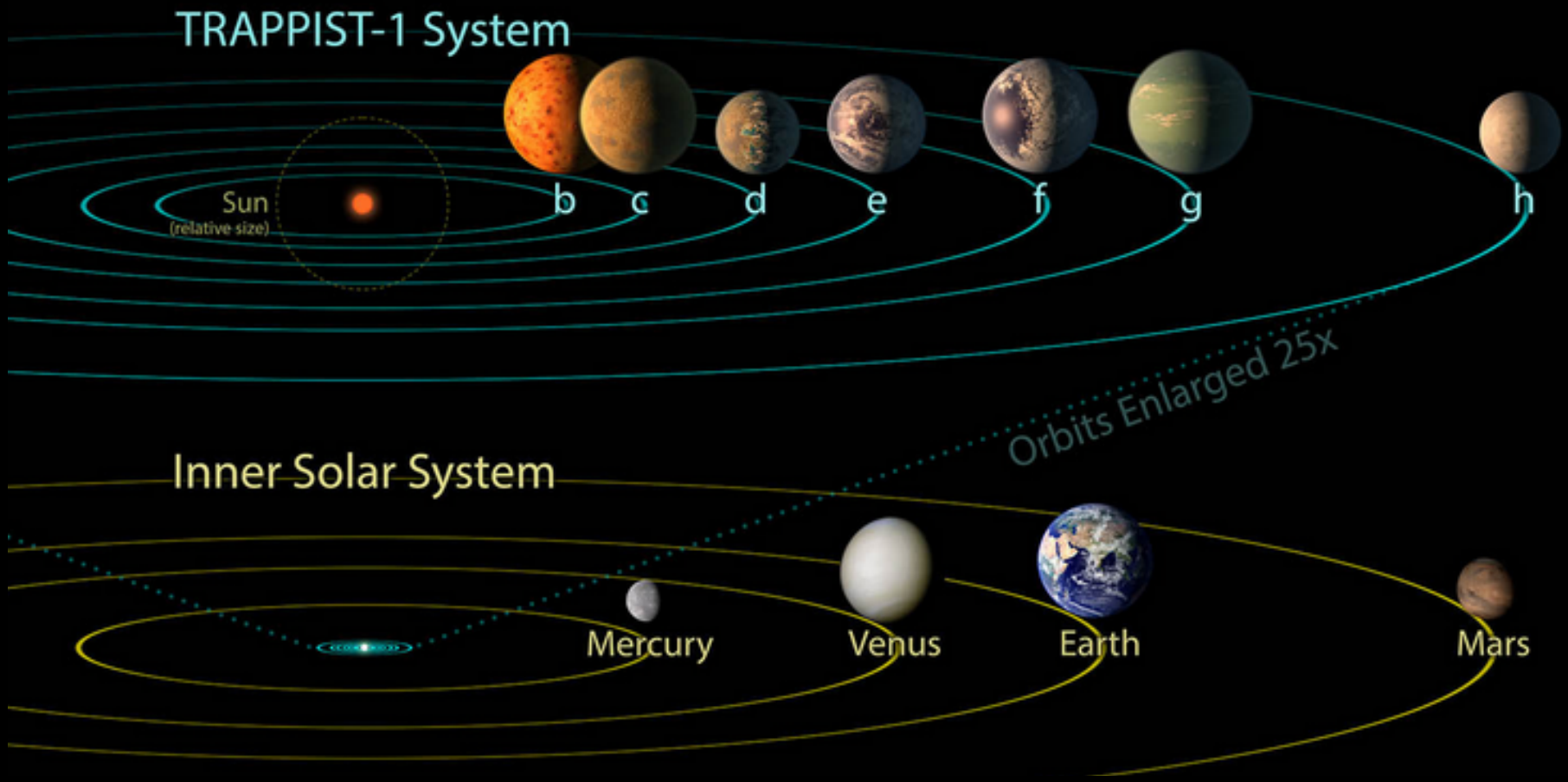
2. Small planets are the most common type in the Galaxy

3. Earth-sized (0.5 to 2 Earth radii) planets in the Habitable Zone are common





Trappist-1 Discovery



Transiting Exoplanet Survey Satellite (TESS)

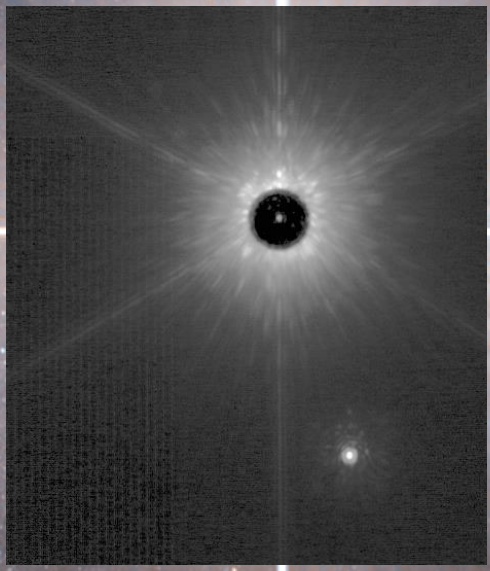
NN-EXPLORE WIYN 3.5-meter Telescope

Ground-based Extreme Precision Radial Velocity (<30 cms^{-1})

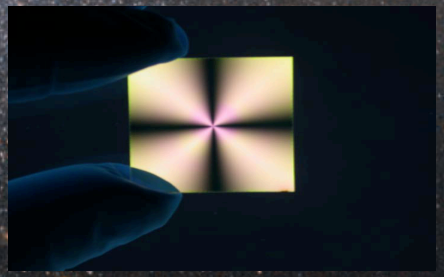
Starlight Suppression

The Key to the Search for Life on Earth-sized Exoplanets

External Occulters
(Starshades)



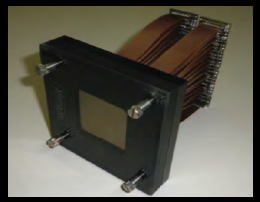
Internal Occulters
(Coronagraphs)



Coronagraph/Telescope Technology Needs

Contrast

Coronagraph architectures



Deformable mirrors

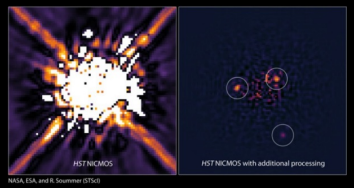
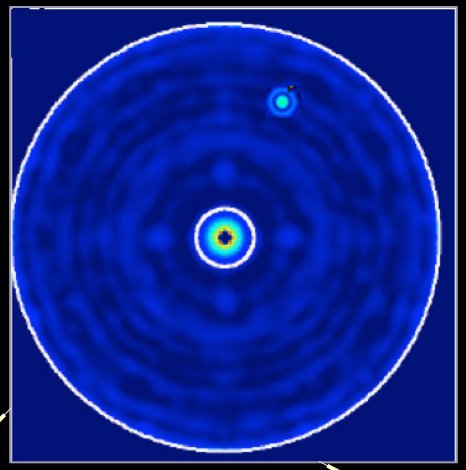
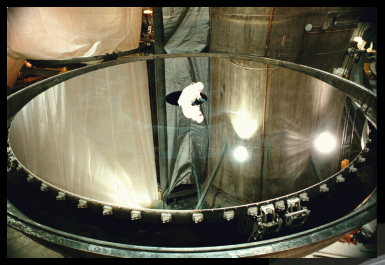


Image post-processing



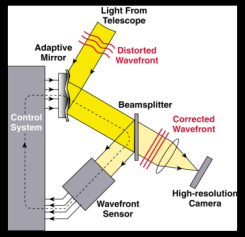
Angular Resolution



Large monolith

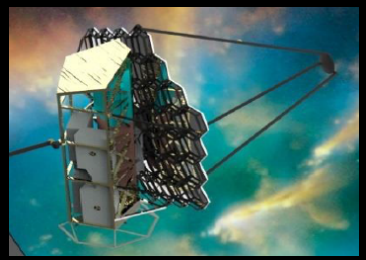
Segmented

Contrast Stability



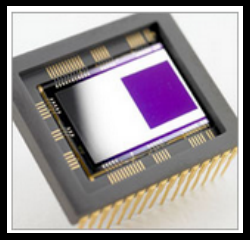
Wavefront sensing and control

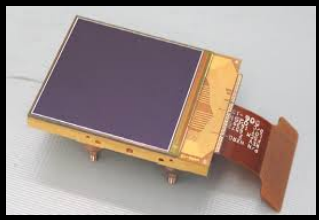
Segment phasing and rigid body sensing and control



Telescope vibration sensing and control

Detection Sensitivity

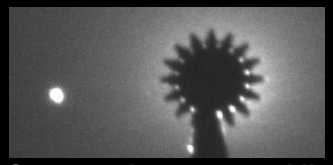




Ultra-low noise visible and infrared detectors

Starshade Technology Needs

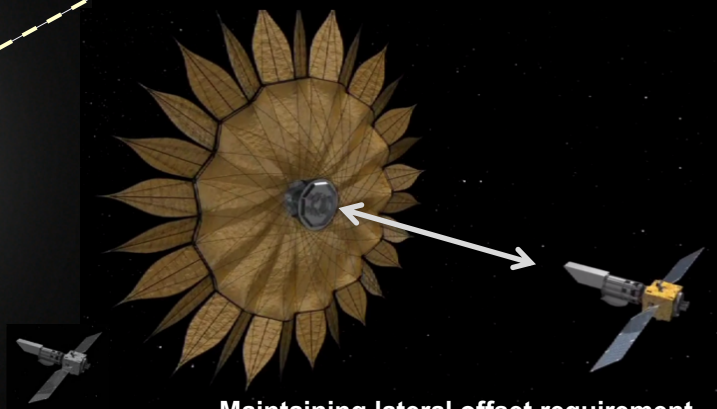
1) Starlight Suppression



Suppressing scattered light off petal edges from off-axis Sunlight (S-2)

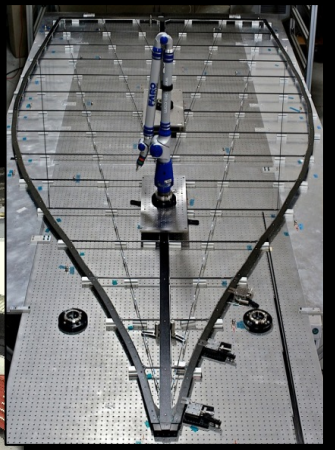
Suppressing diffracted light from on-axis starlight (S-1)

2) Formation Sensing and Control



Maintaining lateral offset requirement between the spacecrafts (S-3)

3) Deployment Accuracy and Shape Stability



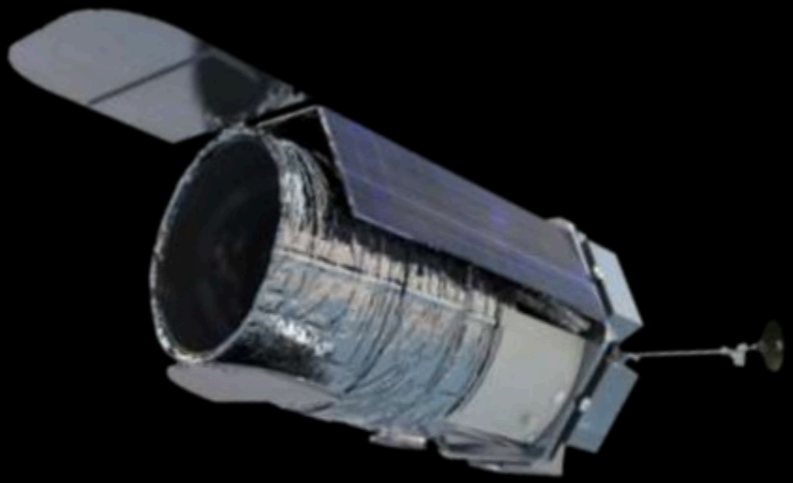
Fabricating the petals to high accuracy (S-4)

Positioning the petals to high accuracy, blocking on-axis starlight, maintaining overall shape on a highly stable structure (S-5)

S-# corresponds to ExEP Starshade Technology Gap number
http://exoplanets.nasa.gov/exep/technology/gap-lists

WFIRST / AFTA Coronagraph

Direct Imaging of our Nearest Exoplanet Neighbors

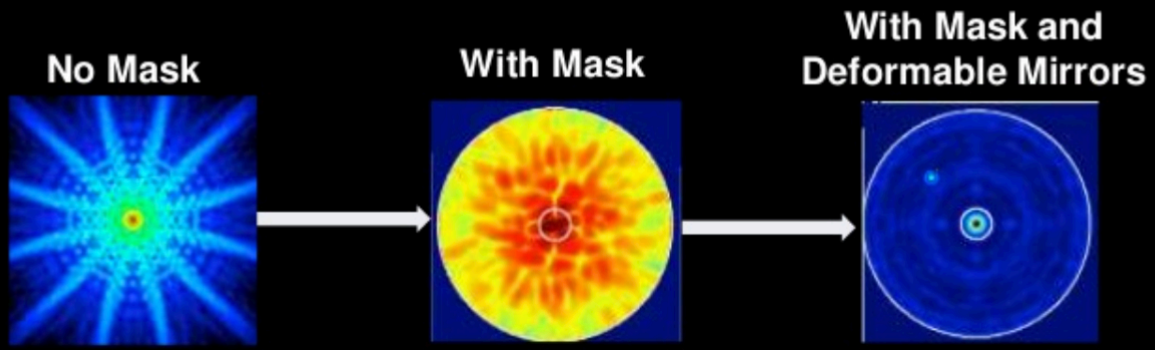


Coronagraph Instrument

- Imaging and spectral channels
- 0.4 – 1 μm bandpass
- ≤ 10^{-9} detection contrast
- 100 mas inner working angle at 0.4 μm
- R ~ 70

Coronagraph Science

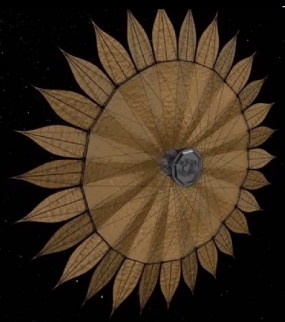
- Imaging and spectroscopy of exoplanet atmospheres down to a few Earth masses
- Study populations of debris disks



Coronagraph will develop the technologies for New Worlds Telescope mission

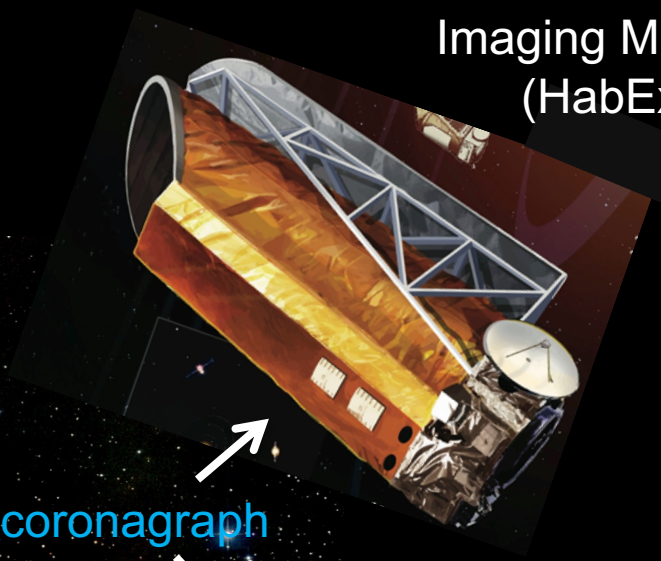
Possible New Worlds Exoplanet Telescopes

(mid 2030s)

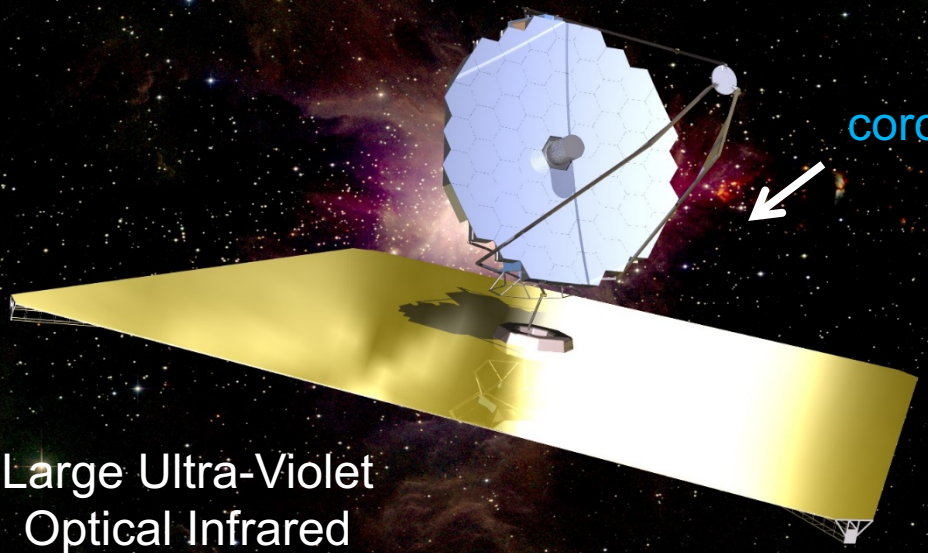


starshade

Habitable Exoplanet Imaging Mission (HabEx)



coronagraph



Large Ultra-Violet Optical Infrared Telescope (LUVOIR)

Origins Space Telescope (OST)

The Exoplanet Travel Bureau!